Platooning Trajectory and Signal Phasing Optimization for Connected Automated Vehicles in Coordinated Arterials

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Motivation

- In the U.S current signal control strategies account for 295 million vehicle-hours of delay on major roadways alone
- Simulation results suggest that it is possible to reduce delays by exploiting CAVs capabilities
- Several studies have developed signal control algorithms using CAVs at the intersection level, but there are few such studies for arterials

Objective

To develop a heuristic framework to jointly optimize (**I**) Connected Automated Vehicles (CAVs) trajectories, and (**II**) Signal Phasing and Timing (SPaT) in coordinated arterials.

I. Trajectory Optimization Methodology

A heuristic approach was developed to adjust CAVs trajectories using the kinematics equations (variable acceleration case) according to vehicles' location (Leader/Follower).

$$x(t)_{l,n} = x(t_0) + \int_{t_0}^{t} v(t)dt$$
$$v(t)_{l,n} = v(t_0) + \int_{t_0}^{t} \alpha(t)dt$$
$$\alpha(t)_{l,n} = y - zt$$

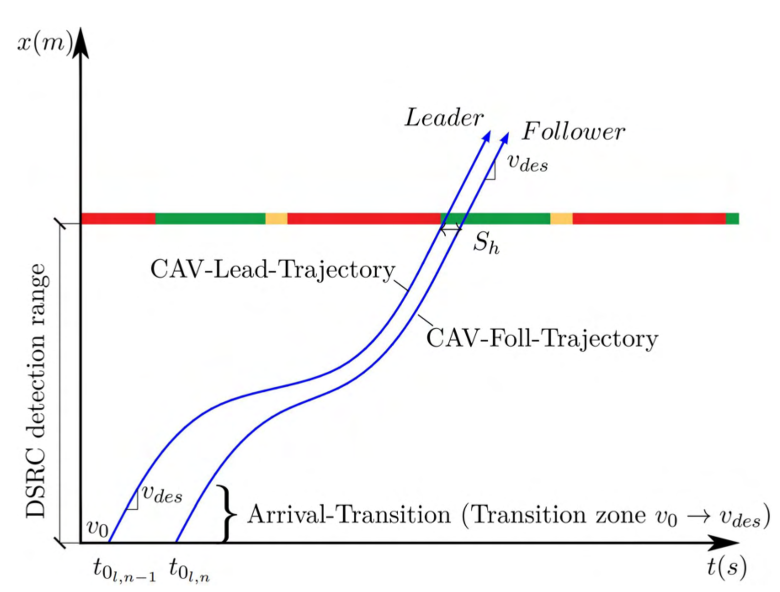

Fig. 1: Concept of trajectory optimization algorithms.

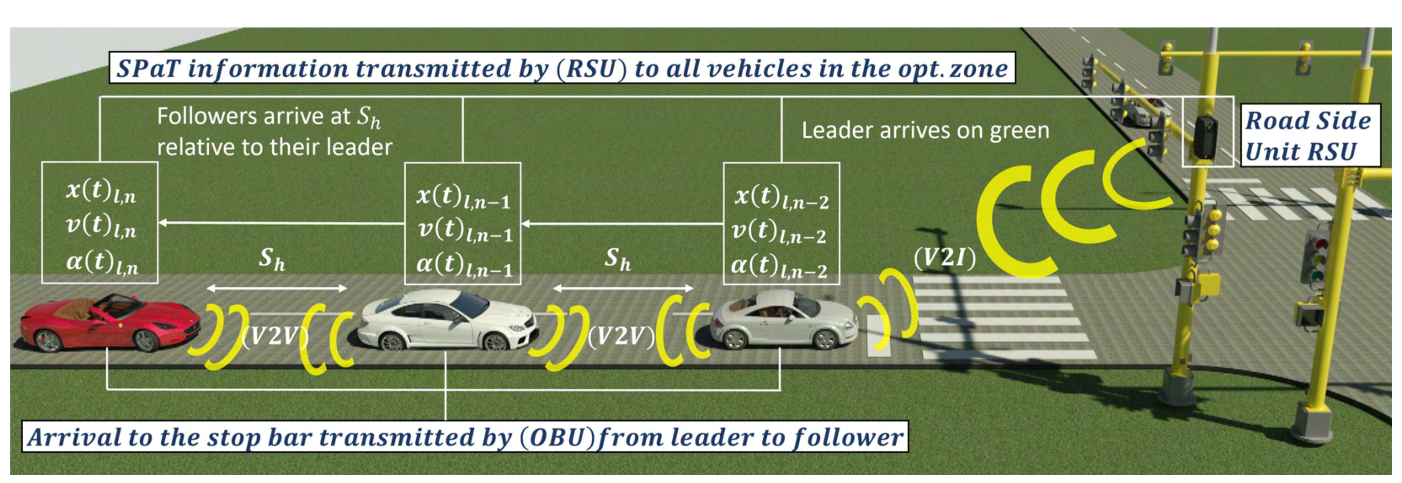

Fig. 2: Conceptual physical framework.

I. Simulation Experiments and Results

Simulation results showed that the trajectory optimization framework successfully form platoons at the saturation headway (S_h) without collision. The results showed that travel time and delay are reduced by (8-22%) and (11-23%), respectively.

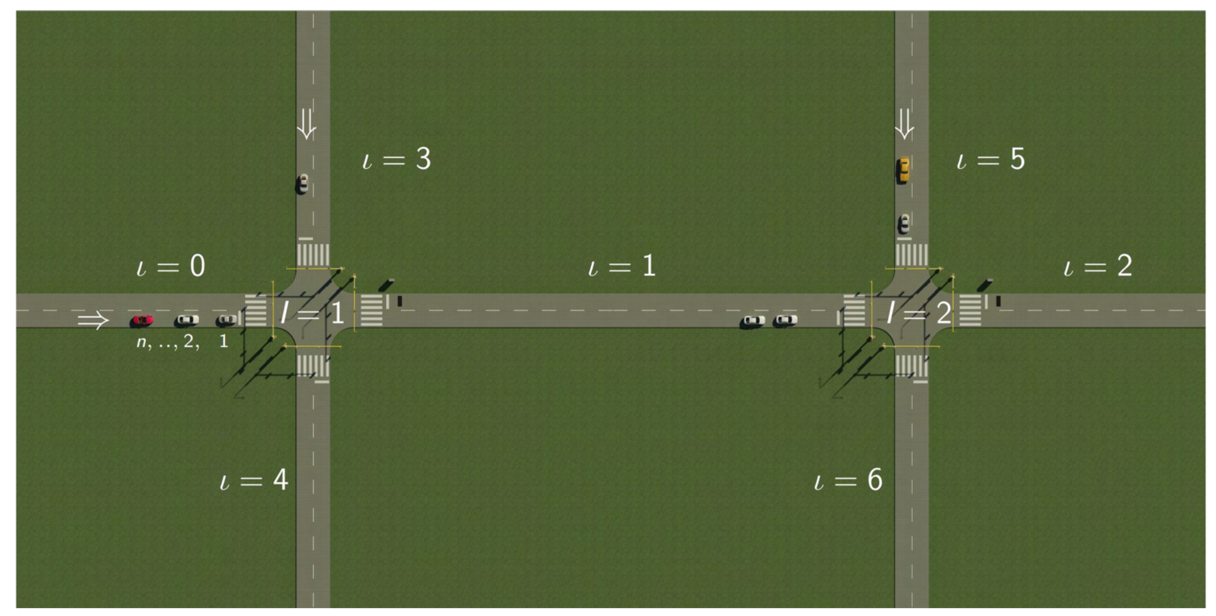

Fig. 3: Study arterial for simulation experiments.

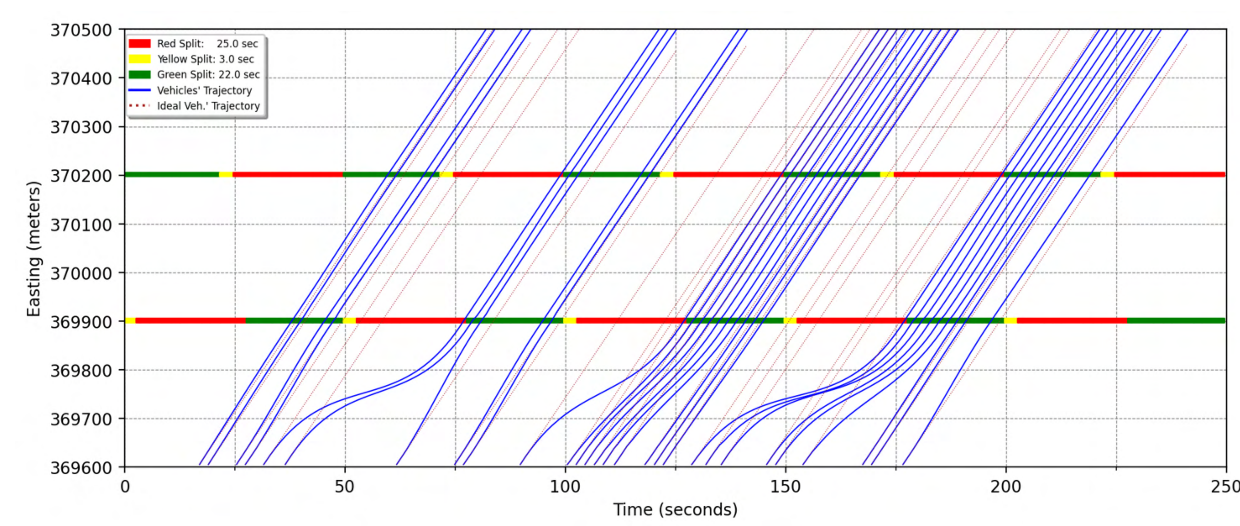

Fig. 4: Time-Space Diagram.

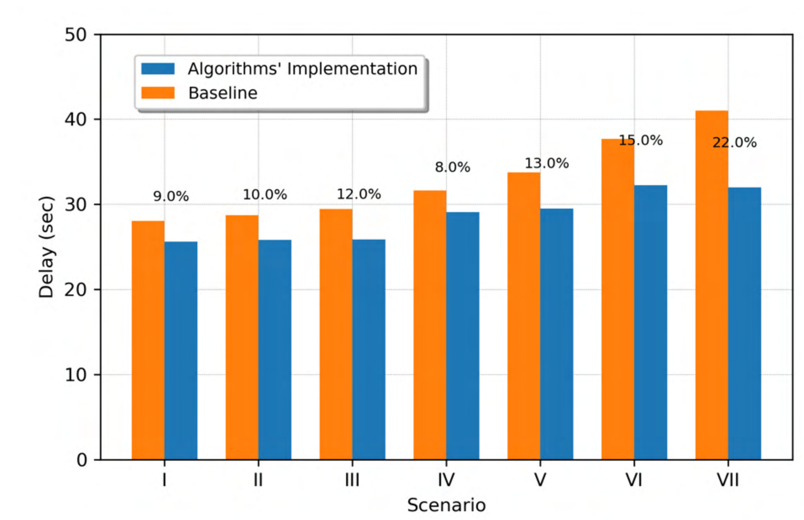

Fig. 5: Average Network Travel Time Improvements.

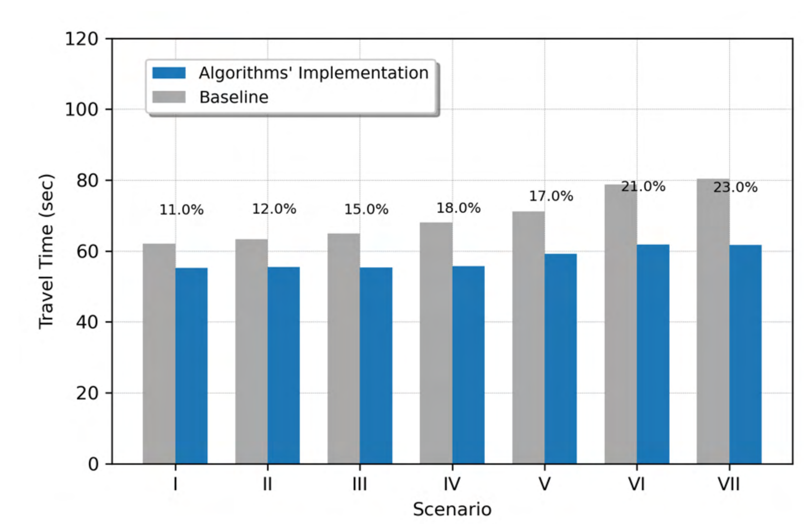

Fig. 6: Average Network Delay Improvements.

II. SPaT Optimization Methodology

A search-based algorithm is designed to optimize the SPaT. A novel Performance Index (PI) is set as the objective function. The PI represents how vehicles' trajectories deviates from their ideal trajectory.

$$\max \quad PI = \frac{1}{V}\sum_{l\in L}\sum_{n\in V_l}\left(\frac{\tau}{\psi}\right)_{n,l}$$
$$\text{s.t.} \quad V_l \leq K;\ \forall l \in L$$
$$\tau_{n,l},\ \psi_{n,l} \geq 0$$
$$V \in \mathbb{Z}^+$$

where:

- L: Set of incoming lanes
- V: Set of all vehicles in V_l; $\forall\, l \ \in L$
- τ: Ideal time to the stop bar
- ψ: Actual time to the stop bar
- K Maximum number of vehicles that can be served at the S_h during the green interval

II. Preliminary Results

Preliminary simulation experiments showed that by adjusting the SPaT according to the PI can reduce travel time and delay by (2-8%) compared to (I).

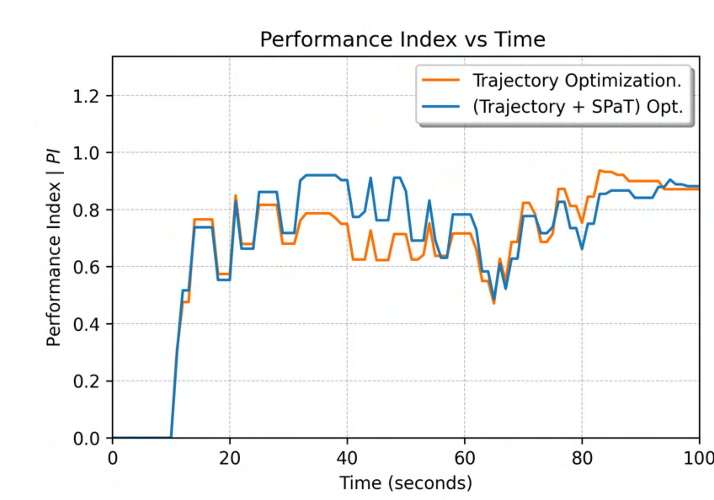

Fig. 7: Comparison of PI variation over time.

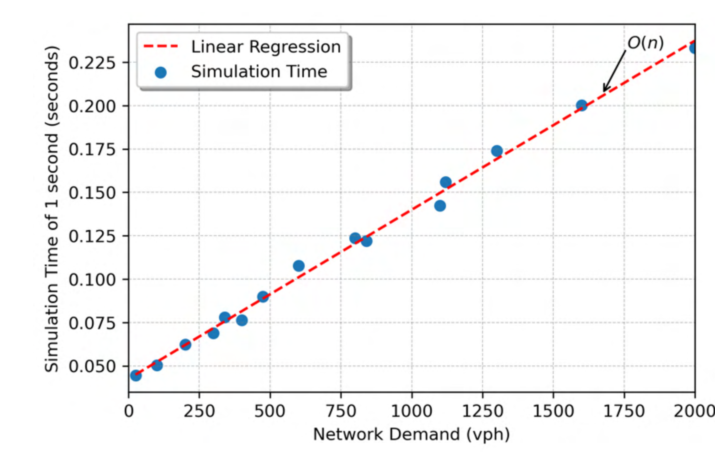

Fig. 8: Empirical time complexity.

Remarks

The time complexity of the algorithms' is quadratic $O(n^2)$. This framework can be extended to Connected-Vehicles (CVs). It is expected that this joint optimization framework will outperformed the previous approach.